General Station Troubleshooting
and
CONT05 Station Verification

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Overview

- Outline of equipment tests that stations should conduct periodically is in section “More extensive testing” of Experiment Pre-checks workshop notes.
- This workshop will go into details of each of these tests, as well as others.
- Every station involved in CONT05 should conduct these tests by the end of June 2005.
- Detailed written instructions for the pre-CONT05 tests will be forthcoming soon!

Antenna pointing offsets

- Measure pointing offsets over the full az/el range of the antenna, by observing multiple sources over a wide range of declinations over a 24-hour period
  - Source size should be ≤X-band beamwidth
- Verify that pointing errors are
  - typically < 0.1 FWHM X-band beamwidth
  - always < 0.3 FWHM X-band beamwidth

System Equivalent Flux Density

- Measure SEFD in each frequency channel on a strong source of known flux density.
  - Use FS command **onoff**.
  - Or measure system temperatures on and off source separately, and calculate:

    SEFD = (source flux density) x Tsys_off / (Tsys_on – Tsys_off)
- Repeat measurements, on same source and other sources, to check consistency.

Phase cal power level

- Measure fractional power contributed by phase cal to total system power in each channel in two ways:
  - Using **tpical** and **tpi** commands, measure baseband total power levels with cal on and off, respectively; then compute fractional power = (tpical – tpi) / (tpi – tpzero) .
  - Measure amplitude of pcal tones in each channel using **pcal** command of Mk4 decoder.
    - FS **dqa** command can measure pcal amp at 10 kHz.
- Check for consistency between results of two methods. Discrepancy may point to modulation of phase cal or LO.

Spurious phase cal signals

- Use Mk4 decoder **pcal** command to measure amplitude of every pcal tone (or **dqa** to measure 10-kHz amp) in each channel with
  - phase cal on
  - phase cal off
    - by disconnecting 5 MHz signal to phase cal antenna unit
    - separately, by turning off ground unit switch, if available
  - phase cal on but receiver LO unlocked
- To dig deeper into noise, use low-frequency FFT analyzer to measure power level of 10-kHz pcal tone in each channel, under same 3-4 conditions as above.
  - If pcal tone used at correlator is not at 10 kHz, it will be necessary to shift the VC/BBC LO frequency to put tone at 10 kHz.

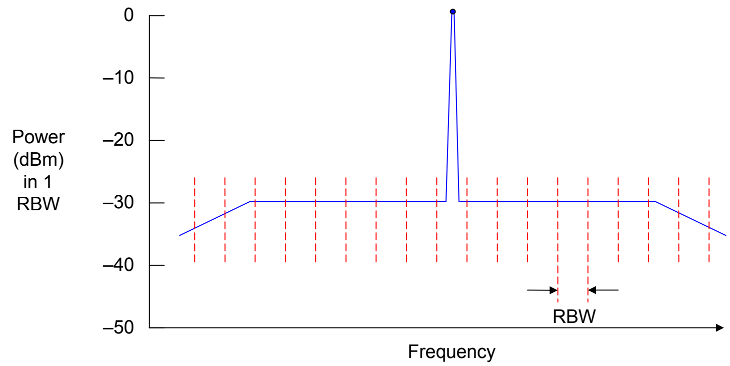
VC/BBC tests: image rejection & LO lock

- USB/LSB image rejection
  - Use **dqa** or **pcal** command, or spectrum analyzer, to measure phase cal amplitude in both sidebands of each channel.
  - Amplitudes in two sidebands should differ by >20 dB (factor of >10 in voltage).
  - Measure at several frequencies spread across baseband, if possible.
- Check that LO locks over full frequency range:
  - 100-500 MHz for Mk4
  - 500-1000 MHz for VLBA

VC/BBC LO phase noise

- Measure LO phase noise at 2-3 LO frequencies
  - Test tone method –
    - Turn off phase cal.
    - Using a signal generator known to have low phase noise, inject a test tone at frequency xxx.xx MHz into IF.
    - Set VC/BBC LO to xxx.xx + 0.01 MHz.
    - Observe 10-kHz beat signal between test tone and LO in LSB output on oscilloscope. Measure RMS jitter in zero-crossing time of signal.
  - Spectrum method –
    - Use method described in spectrum analyzer workshop to measure phase noise and RMS phase jitter.
- Compare measured jitter against VC/BBC LO specification:
  - Mk4: rms < 4° below 450 MHz, rms < 9° above 450 MHz
  - VLBA: rms < 2°
- Compare spectrum against reference spectrum.

Measuring LO phase noise on spectrum analyzer



• Phase noise = total power in two modulation sidebands

• RMS phase jitter (radians) = sqrt[(power in 2 sidebands) / (power in carrier)]

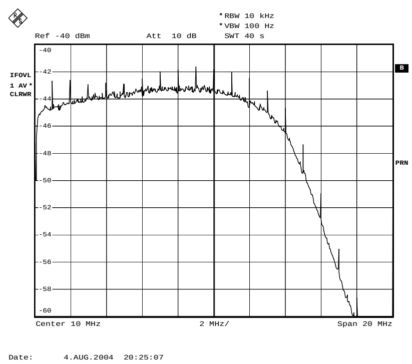
VC/BBC baseband bandpass shape

- Using spectrum analzyer, measure shape of baseband spectrum in each frequency channel, and compare against ideal.
- Ideal bandpass shape of baseband signal, whether measured at VC/BBC analog output or after digitization in sampler, is…
  - Flat to <1 dB from near DC to 0.8 x filter BW
  - Down by 3 dB at 0.9 x filter BW
  - Down by 7-8 dB at bandedge
- Shape may be affected by RF/IF filter characteristics, RFI, ripple due to impedance mismatches, etc.

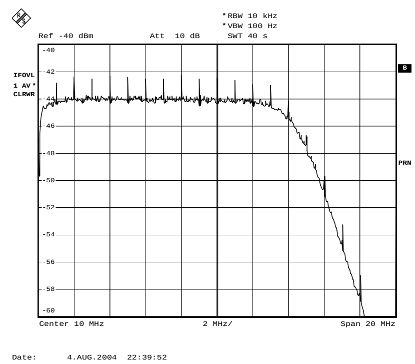
VC bandpass spectrum example: Wettzell

16-MHz-BW spectra measured with spectrum analzyer

VC01 LSB – not so good!



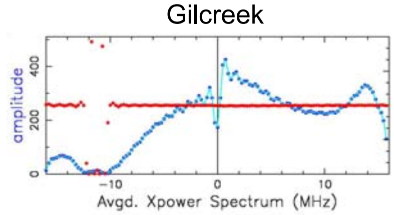
VC01 USB – good



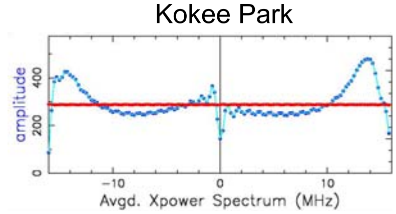
Examples of spectra from correlator

16-MHz-BW spectra for channel X1 LSB & USB in RD0504

Gilcreek



Kokee Park



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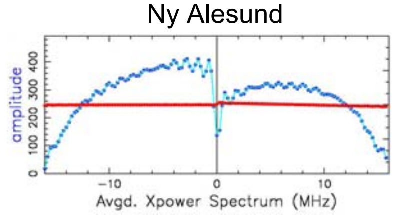
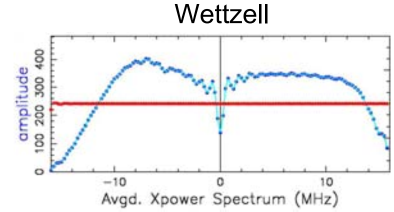


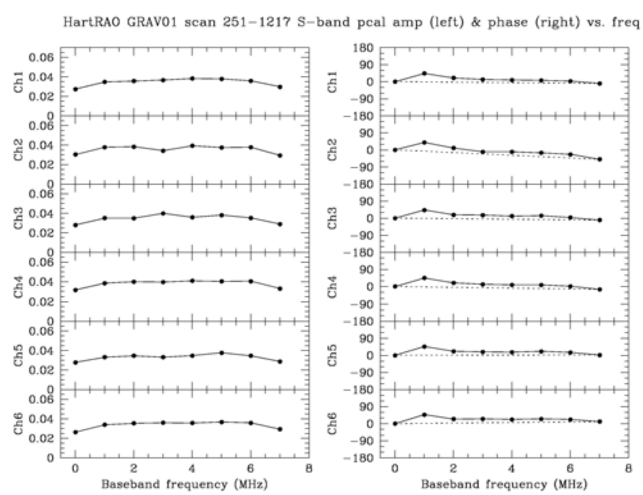
Wettzell



Baseband spectrum from phase cal

- A low-resolution spectrum of each digitized baseband signal can be obtained from frequency dependence of phase cal amplitudes.
- Use Mk4 decoder command **pcal** to measure amplitude and phase of all phase cal tones in each channel.
- Phase cal amplitude spectrum is affected by same factors as continuum spectrum, as well as by
  - spurious signals
  - short-term phase coherence
  - image rejection, etc.
- Phase cal phase spectrum has additional information on spurious signals.

Phase cal amp & phase example: HartRAO



Phase shown after subtracting model (phase_10kHz + delay * freq * 360), with delay = -0.19 us.
Dashed straight line connects first and last phase points.

Sample state counts

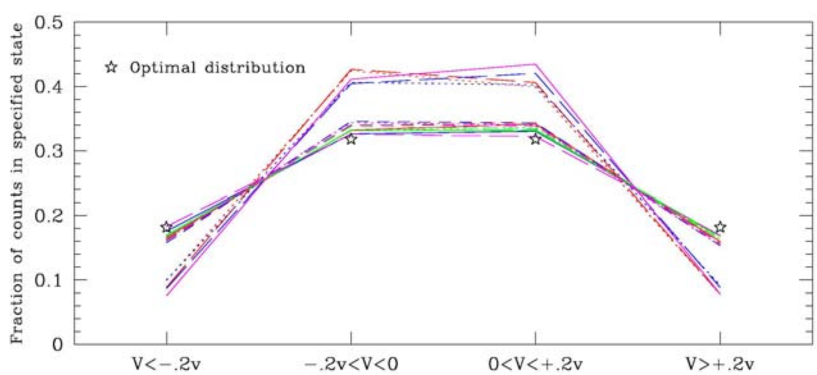
- Sample state statistics should be monitored via Mk4 decoder **samples** command to check for potential problems in analog or digital domain.
- Ideal distribution is

Sample state	*% of total samples*
– –	18%
–	32%
+	32%
+ +	18%

- Deviations from ideal may indicate…
  - Impedance mismatch in VC/BBC→formatter cable
  - No input to sampler
  - VC/BBC AGC circuit not working properly

Example of state counts

Gilcreek RD0504 state counts for all 16 sidebands



Antenna orientation-dependent effects

- As the antenna is slewed slowly in azimuth and elevation over its full range of motion…
  - Use the FS to record cable cal and phase cal amplitude and phase rapidly, with at least 20 sets of data points per azimuth or elevation slew.
  - Observe each IF with a spectrum analyzer and look for in-band RFI and strong out-of-band RFI.
  - Watch cable cal counter for jumps or rapid drifts.
  - Watch S and X phase cal phases on oscilloscope for jumps, rapid drifts, or unusual jitter that might be missed in FS log readings.

Diurnal behavior

- Park antenna at zenith.
- Use **overnite** procedure, or comparable one of your own devising, to log at least the following quantities at 5-minute (or shorter) intervals for 24 hours:
  - Phase cal phases and amps in 2 X-band channels
  - Phase cal phases and amps in 2 S-band channels
  - Cable cal
  - Formatter-GPS time interval
  - Weather data
  - Receiver monitor points
  - System temperatures in all channels
- Examine logged data for unexpected variations.

Short-term variations

- Park antenna at zenith.
- For 10 minutes, record following quantities every 15 seconds:
  - Phase cal phases and amps in 2 X-band channels
  - Phase cal phases and amps in 2 S-band channels
  - Cable cal
- Examine logged values for systematic variations or unusual short-term variations.

Cable cal

- Is cable reading stable to < 2 microsec peak-peak on time scales of 1-30 seconds?
  - It should not be necessary to operate counter in averaging mode to achieve this level of stability. Counter should be operated in single-sample mode.
- With test cable of known length inserted, does counter reading change by correct amount?
- On Mk4 ground unit, is phase meter between ¼ and ¾ of full scale?

Rack power

- Use oscilloscope to measure ripple and noise on DAT/DAR power supplies.
  - Low-frequency ripple should be < 10 mV pk-pk.
  - Total noise should be <100 mV pk-pk.
- Use multimeter to measure DC supply voltages *at the modules*, not at the power supply terminals, as there may be significant IR voltage drop from the supply to the module. Measured voltage should be within 0.1 V of design voltage.

Meteorological sensors

- Temporal stability
  - Barometer should be stable to 0.1 mb over a few minutes.
  - Temperature should be stable to 0.1 deg C over a few minutes.
- Barometer should be calibrated annually.
- Measure barometer offset relative to a local authority, e.g., airport.

Mark 5A checks

- Information on testing and trouble-shooting Mark 5A systems is available in the notes for the Mark 5A Verification and Use workshop.
- Specific instructions on pre-CONT05 Mark 5A tests will be included in the forthcoming test plan.